ACCELERATOR ISSUES: THE NEXT ITERATION

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VLHC Magnet Technologies Workshop

Outline

Accelerator Issues

Strategic Questions

ACCELERATOR ISSUES

The VLHC represents a fifth generation hadron collider. As such we are predisposed to think that there are not looming accelerator physics issues that could call into question the basic feasibility of such a machine. The overwhelming question is instead one of cost.

Nevertheless, attention has to be paid to the usual accelerator physics suspects (Mike Syphers list):

- Magnet aperture and field quality
- Lattice design
- Synchrotron radiation
- Instabilities
- Longitudinal parameters
- Beam-beam
- Emittance evolution and control
- Energy deposition
- Correction schemes

This is a good list to which I would add a few more:

- Beam stored energy
- Optimum bunch spacing
- Optimum magnet field (whatever that means)

Þ **The question is which of these impact choices in magnet development and how.**

These issues cannot be discussed devoid of a context.

-> Since Snowmass96 this has been a 100 TeV collider with a luminosity of $\sim 1 \times 10^{34}$ $cm^{-2} sec^{-1}$

Magnet Aperture and Field Quality

The required magnet aperture depends upon the

- **Injection energy**
- **Injected beam emittance**
- The ratio of physical aperture to good field aperture

The required field quality is well established through existing hadron colliders. It doesn't require a lot of computation, just looking at what other people have done to establish field quality requirements at the peak energy. The real issue is what is the

Injection Energy

What is the required low field performance required of the magnet in the presence of a realistic correction magnet system?

Instabilities

Raising instability thresholds can feedback into aperture requirements on the vacuum chamber as in the case of the low field machine. While this does not appear to be as big a deal now as several years ago, its prudent to remain on the lookout.

Energy Deposition

The beam stored energy in the VLHC is a big deal (measured in GJoules). Protecting from catastrophic loss is only peripherally related to magnet design issues.

Synchrotron Radiation

This is the biggest deal of all (in my opinion).

- May place an upper limit on the magnetic field that needs to be explored
- Direct impact on the design of the entire cryogenic guts of the magnet.
- Direct impact on design of the cryogenic distribution system.

Some parametric relations:

$$P \propto E^2 B^2 N_{TOT}$$

$$\frac{dP}{dz} \propto EB^3 N_{TOT}$$

Circumference	**200**	**km**				
Packing Factor	**0.75**					
B (Tesla)	**2**	**5**	**10**	**13**	**16**	
E_{CM} (TeV)	**29**	**72**	**143**	**186**	**229**	
Protons/bunch	2.50E+10	2.50E+10	2.50E+10	2.50E+10	2.50E+10	
Transverse emittance (πmm-mr, 95%, norm)	15	15	15	15	15	
β^* (m)	0.25	0.25	0.25	0.25	0.25	
Rev. Frequency (Hz)	1499	1499	1499	1499	1499	
Bunches	44475	44475	44475	44475	44475	
Bunch Spacing (nsec)	15	15	15	15	15	
Beam size at IP (μm, rms)	6.40	4.05	2.86	2.51	2.26	
Luminosity	**8.1E+33**	**2.0E+34**	**4.0E+34**	**5.3E+34**	**6.5E+34**	
Total Protons (per ring)	1.11E+15	1.11E+15	1.11E+15	1.11E+15	1.11E+15	
Stored Energy (GJ, per ring)	**3**	**6**	**13**	**17**	**20**	
Synchrotron Radiation						
Energy Loss per Turn (MeV)	0.014	0.537	8.585	24.521	56.265	
Damping Time (hours ,transverse)	386.5	24.7	3.1	1.4	0.8	
Radiated Power (MW, per ring)	0.004	0.143	2.289	6.539	15.004	
Linear Power Density(W/m)	0.02	0.95	15.26	43.59	100.03	

STRATEGIC QUESTIONS

Easy Questions

What is motivating the R&D program?

- Is it high field magnet R&D? or
- Is it high field accelerator magnet R&D?

If accelerator magnet R&D, what is providing the context for the work?

- Is it a small (100 km) ring supporting a high field, 100 TeV ring? or
- Is it a large (600 km) ring supporting a low field, 100 TeV ring? or
- Is it a staged scenario based on an intermediate circumference ring?

Harder Questions

How much of a benefit is synchrotron radiation, really?

- Are damping times measured in hours really all they're cracked up to be?

Is there a magnetic field that is "too high"?

- At what point does the synchrotron radiation load become unmanagable?

Is there a magnetic field that is “too low”?

- At what point does the circumference of the tunnel become unmanagable (for either technical or cost reasons)?

How much systems engineering should be feeding into the magnet development?

- How much emphasis should be placed on understanding the power and cryogenics distribution systems that would support a particular magnet?

Hard Questions

When and how should specific technologies be abandoned?

- When and how should cost goals be established?
- When and how should technical milestones be established?
- How do we evaluate progress relative to such milestones?

SUMMARY

Real progress has been made on superconducting magnets for future hadron facilities over the last year.

This work is largely proceeding within the context of specific facilities. Most of the questions listed as harder and hard do not yet require answers.

So, we need to continue in this mode, but keep the hard questions in mind because they will ultimately become relavant.